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Lean Manufacturing - A Powerfull Tool for Reducing Waste During the Processes

Lean manufacturing provides a new management approach for many small and medium size manufacturers, especially older firms organized and managed under traditional push systems. Improvement results can be dramatic in terms of quality, cycle times, and customer responsiveness. Lean manufacturing is more than a set of tools and techniques and has been widely adopted by many production companies. Lean manufacturing is a culture in which all employees continuously look for ways to improve processes. In the present article are presented the Lean Manufacturing tools, like kaizen, Kanban, poka-yoke witch a company can use to reduce the waste(muda) during a production process. The paper contains also, the most common seven types of waste from production and some examples from our daily activity.

Keywords: *lean manufacturing, waste, lean tools, Kanban, leaner company*

1. Introduction

Lean manufacturing it is a comprehensive set of techniques that, when combined and matured, will allow you to reduce and then eliminate the seven wastes. This system not only will make your company Leaner, but subsequently more flexible and more responsive by reducing waste [1]. Principles of lean thinking have been broadly accepted by many manufacturing operations and have been applied successfully across many disciplines. While many researchers and practitioners have studied and commented on lean manufacturing, it is very difficult to find a concise definition which everyone agrees. Lean manufacturing is most frequently associated with the elimination of seven important wastes to ameliorate the effects of variability in supply, processing time or demand. Some authors like, Liker and Wu defined lean manufacturing like a philosophy of manufacturing that focuses on delivering the highest quality product on time and at the lowest cost. Others like, Worley defined like a systematic removal of waste by all members of the organization from all areas of the value stream. Lean manufacturing has become an integrated system composed of highly interrelated elements and a wide variety of management practices, including Just-in-Time (JIT), quality systems, work teams, cellular manufacturing. The purpose of implementing it is to increase productivity, reduce lead time and cost, and improve quality. As an integrative concept, the adoption of lean manufacturing can be characterized by a collective set of key areas or factors. These key areas encompass a broad array of practices which are believed to be critical for its implementation. They are, scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, and tools and techniques. Scheduling has been widely discussed in lean manufacturing. Effective schedules improve the ability to meet customer orders, drive down inventories by allowing smaller lot sizes, and reduce work in processes. Pull methods such as Kanban, and lot size reduction are commonly used to reduce storage and inventories and to avoid overproduction [2-8].

2. Description of most common types of waste

Lean manufacturing encompasses many different strategies and activities that are familiar to most industrial engineers. Lean manufacturing production systems were pioneered in Japan. Lean manufacturing began to be implemented in the West's automotive industry from the mid-1980s onwards. Central to the philosophy of lean – and embraced to the full, it assumes the form of an entirely new cultural approach to manufacturing – is a flow-based production architecture in which simplicity is promoted and waste aborted.

With the elimination of waste, quality improves while production time and costs are reduced, but must be something the company carries out on a regular basis. A important key component of lean manufacturing for reduction of the waste is flow and smart automation [9].

The three basic types of waste that occur in production are:

- **Muri:** has to do with overburden, which is all the unreasonable work that management assigns to workers and machines because of poor organization. Muri has to do with the planning and design phase of production.
- **Mura:** has to do with unevenness and fluctuations in the implementation and operations phase of production. Waste occurs when there are fluctuations in volume and quality.
- **Muda:** has to do with waste elimination and is done at the end of the production process. Management oversees Muda and uses what they learn to eliminate the deeper problems in Muri and Mura.

Poor arrangement of the workplace in terms of workers and machinery and doing jobs inefficiently out of habit are major forms of waste in modern manufacturing. Because of this, lean manufacturing requires a new, non-traditional way of looking at things. This involves adopting the philosophy and culture of lean. Unfortunately, most lean manufacturers focus on lean tools and methods, which leads to problems in becoming truly lean. The tools are work arounds to help implement a lean approach to business. After the Toyota company model, the waste is divide into the following seven categories, that are addressed by lean theory and presented in figure 1.

Figure 1. The seven types of waste

Traditional batch manufacturing separates processes with buffers. Figure 2 presents three operations with plenty of inventory coming into the operation and leaving the operation. This buffers the operations so that each can all work at different pace and equipment breakdowns will not influence later operations until the inventory buffer is depleted. If the only goal was to keep everybody working as much as possible, this would seem to make sense. This kind of system have some inefficiencies like: long lead times due to inventory buffers; feedback from later operations (customers) to earlier operations is delayed; when a defect is discovered it is not clear when or why it was produced; extra floor space is needed; when shifting to a new product (e.g., A to B) there is a large buffer of parts to be moved and handled, extra handling is necessary (potential damage) and extra inventory costs money [10].

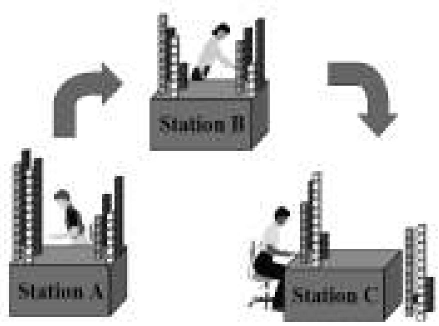

Figure 2. Batch and queue processing

a. Overproduction

As the name implies, means producing more than you need to produce. This is the most egregious of all the wastes since it not only is a waste itself but aggravates the other six wastes. For example, the overproduced volume must be transported, stored, inspected, and probably has some defective material as well. Overproduction is not only the production of product you cannot sell, it is also making the product too early. An interesting note about overproduction is that nearly all of the overproduction is planned overproduction. It is planned, and often for a variety of good-sounding reasons. However, upon scrutiny, all planned overproduction should be eliminated. For instance, to assure they have sufficient finished goods, many companies plan for extra production and purchase extra raw materials because they will have quality fall out during the process. This planning process is really just guesswork and adds considerably to the variation in the process. Even worse, many companies work hard to fine-tune this planning process so as to minimize the waste of planned overproduction. Thus, we have the already scarce supply of technical manpower working to remove the planned overproduction, which is caused really by the planning process, which saw a need because there is a quality problem which affects production quantities [11].

b. Unnecessary inventory

This is the classic waste. All inventories are waste unless the inventory translates directly into sales. It makes no difference whether the inventory is raw materials, work in progress (WIP) or finished goods. It is waste if it does not directly protect sales. The level of equipment support should be given attention in lean manufacturing because some manufacturing processes rely heavily on their equipment to produce products. Unexpected machine downtime would result in line stoppage and decrease productivity. Therefore, equipment is a vital area in which maintenance and reduction of setup time play an important role to avoid process disturbance. Lean manufacturing requires machines which are reliable and efficient. Inventories can be reduced when machine downtime is minimized [12].

c. Transportation

This is the waste of moving parts around. It occurs between processing steps, between processing lines, and happens when product is shipped to the customer.

d. Overprocessing

This is the waste of processing a product beyond what the customer wants. Engineers who make specifications that are beyond the needs of the customer often create this waste in the design stage. Choosing poor processing equipment or inefficient processing equipment increase this waste also.

e. Waiting

This is simply workers not working for whatever reason. It could be shortterm waiting, such as what occurs in an unbalanced line, or longer waits, such as for stock outs or machinery failure [13].

f. Unnecessary motion

This is the unnecessary movement of people, such as operators and mechanics walking around, looking for tools or materials. All too often, this is frequently overlooked as a waste. After all, the people are active; they are moving; they look busy. Work design and workstation design is a key factor here.

g. Making defective parts

This waste is usually called scrap. These activities add cost and do not cause a product to be transformed into a more complete product. They are non-value-added activities, as they add no value from the customer's point of view. Traditional batch manufacturing separates processes with buffers. Figure 2 presents three operations with plenty of inventory coming into the operation and leaving the operation. This buffers the operations so that each can all work at different pace and equipment breakdowns will not influence later operations until the inventory buffer is depleted. If the only goal was to keep everybody working as much as possible, this would seem to make sense. This kind of system have some inefficiencies like: long lead times due to inventory buffers; feedback from later operations (customers) to earlier operations is delayed; when a defect is discovered it is not clear when or why it was produced; extra floor space is needed; when shifting to a new product (ex. A to B) there is a large buffer of parts to be moved and handled, extra handling is necessary (potential damage); extra inventory costs money. Continuous flow processing is a much better approach for overall system performance. The ideal is a one piece flow which is best illustrated by Henry Ford's moving assembly line. In parts operations we talk about one piece flow cells. With one piece flow all operations are synchronized. It becomes immediately apparent where the bottleneck operation is and efforts can focus on that operation. The effects of poor preventative maintenance are felt immediately. Quality problems passed on to the next station are discovered immediately. As you can see in figure 3 the operators are linked together which enhances teamwork and problem solving. Using this continuous flow in production a company can obtain some advantages like: production lead times are short; imbalances in operation timing (bottlenecks) are apparent – improvement can focus on bottlenecks; constant motivation for improvement –problems have immediate production impact; operations can quickly shift to a new product (e.g., A to B) without interrupting the flow, each operation makes just what is needed when it is needed;. there is minimum part handling; defects are immediately apparent and the underlying cause can be quickly determined; inventory holding costs are minimized [14-16].

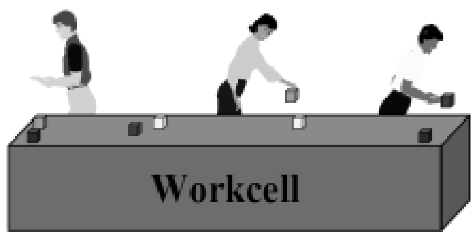

Figure 3. Example of continuous flow

2.1. Lean manufacturing tools used for reducing waste

During a process by eliminating waste (muda), quality is improved, production time and costs are reduced. To solve the problem of waste through the instrumentality of Lean Manufacturing can be use several tools, such us:
- constant process analysis (Kaizen);
- "pull" production (Kanban);
- mistake-proofing (Poka-yoke).

2.1.1. Constant process analysis: Kaizen

The Japanese term kaizen literally means "change for the better." And without people who are committed to improving the process, and aligned with management's goals the discipline needed to run a lean manufacturing system will quickly falter. Kaizen is the concept of improving a process by a series of small continuous steps. Often times these improvements are small and hard to measure, however the accumulated effect is significant. Over the years, kaizen has evolved to mean improvement [17].

2.1.2. A pull production system: Kanban

Kanban means sign board. A kanban can be a variety of things, most commonly it is a card, but sometimes it is a cart, while other times it is just a marked space. In all cases, its purpose is to facilitate flow, bring about pull, and limit inventory. It is one of the key tools in the battle to reduce overproduction. Kanban provides two major services to the Lean facility. Kanban provides two types of communication. In both cases, it gives the source, destination, part number, and quantity needed.

The kanban system is very flexible, and many types of kanban can be used. Likewise, as long as they follow the basic rules of Kanban, they can be used in a large variety of ways. However, the majority of kanban follow a standard pattern. Process improvement in a Kanban system is accomplished by the reduction of inventory, witch can be achieved by:

- reducing any of the four replenishment times or reducing the pickup volume by the customer, this is usually achieved by increasing the pickup frequency;
- reductions in any of these items will reduce cycle stock inventory;
- reducing the variation in the production rate, which allows safety stock reductions;
- reducing the variation in the customer demand, which allows buffer stock reductions [18].

The Kanban system it's a powerfull tool for reducing the waste during production because first it is direct communications to produce material, in other words, to supply and the customer. It is the pull signal to produce. Once the product is withdrawn by the customer, at that moment the Kanban tells us exactly what the customer is using, and hence what the customer will need later. This Kanban is sent as fast as possible to the production line. In essence, the kanban system is doing the "talking" to the production system, telling it to produce because some product has been removed. This system easily bypasses all the accounting and planning systems that tend to not only delay this signal but also add variability along the way. The Kanban system is dealing real time with the realities of what is happening on the line. The planning systems deal with what the programmer believed should be happening

Second, Kanban creates an absolute limit on total inventory. Since each kanban represents a certain amount of stock, and the number of kanban are strictly controlled and limited, this creates an upper limit on the inventory. Below is presented a formula witch is using in production to show how Kanbans could flow between a customer cell and a supplier cell [19-20].

Step 1

$$\frac{D\text{esigned daily production rate x replenishment time}}{\textit{available}\ \text{time}} = \textit{Kanban}\ \text{quantity}, (1)$$

Step 2 $$\frac{Kanban \text{ quantity}}{\text{lot size}} = \text{number of cards}, \quad (2)$$

Lot size may be required due to weight, size, A,B,C categorization, setup times, common resources, outside suppliers. Replenishment time that is less than one shift would result in a two-bin system. Replenishment time that is greater than one shift would result in a card system.

For example:

Step 1 $$\frac{90 \text{ pieces x } 15 \text{ hours}}{7.5 \text{ hours}} = 180 \text{ pieces}, \quad (3)$$
$$\text{"A" parts} = 1/2 \text{ day demand, or } 45 \text{ pieces}$$

Step 2 $$180 \text{ pieces} \div 45 \text{ pieces} = 4 \text{ cards}, \quad (4)$$

Every Kanban system should have the minimum identification requirements, witch are: part number, part description, part quantity, point of supply, point of consumption, "one of… cards" (e.g., 1 of 3; 2 of 3; 3 of 3). In figure 4 is presented a typical journey of a Kanban card [21].

Figure 4. A typical journey of a Kanban card

The determination of Kanbans is an important step in the cell design process because Kanbans are the limiting factor for inventory levels (raw material, WIP, finished goods) and are the control element on lead-times. These operational aspects (inventory and lead-time) have a major influence on continuous improvement within a cellular operation [21].

2.1.3. Mistake-proofing: Poka-yoke

Poka-yoke is a series of techniques, limited only by the engineer's imagination. The purpose of poka-yokes is to achieve error proofing of a process activity and thereby make the process more robust. Poka-yokes are also used in the inspection process to achieve 100% inspection. There are two types of inspection poka-yokes: those that control, that is, shut down (the process or isolate the product upon finding a defect) and those that warn the operator.

Work processes across the value stream should also be emphasized in lean manufacturing. Processes should be performed with a minimum of non value added activities in order to reduce waiting time, queuing time, moving time, and other delays. Besides this, standardization of work processes is needed to facilitate efficient, safe work methods and eliminate wastes, while maintaining quality. It ensures a consistent performance and creates a foundation for continuous improvement. Nowadays, a product with high quality is a prerequisite for any manufacturer [22].

3. Some examples of waste in daily activity

3.1. Example 1

For instance, let's say that you observe a person carrying parts from one department to other. This activity takes her 7 minutes. Her rate of pay is 15 € per hour, this makes a cost to her company 0.25 € per minute. The activity in this example cost 1.75 € (7 minutes times 0.25 €) to perform and did not result in a product's becoming more complete in terms of the customer's specification. This person will receive 1.75 € in her next paycheck for this time spent. The company will receive no money from a customer related to this 7-minute activity; it is not an activity that can be invoiced. This person accumulated cost and generated no revenue.

3.2. Example 2

You observe a quality inspector busily performing a final inspection on a completed refrigerator prior to the unit's being shipped to the customer. This inspector is following a checklist and looking for dents, blemishes, correct placement of UL and serial stickers, correct number of shelves and bins, cleanliness, silicone and tape removal, sharp edges on the metal surfaces, correct assembly and placement of screws and fasteners in the unit, door seal integrity and alignment, and so on. This individual is working diligently; she believes that she is performing important work and assuring the customer of a quality product. Upstream operators have performed all operations contributing to the completion of this product. It is a finished product. Looking at (inspecting) the unit cannot change its physical characteristics. The inspector finds the unit to be satisfactory, fills out several quality logs, and allows the unit to proceed to shipping. Inspectors in this company are paid at a rate of 15.45 € per hour and have a fringe benefit package worth 4.50 €. Total cost per hour for this activity is 19.95 €, or 0.33 € per minute. The time required to inspect a unit averages fifteen minutes or so. Let's add this one up. We have 15 minutes per unit, times 0.33 € per minute, times 30 units a shift, times 2 shifts per day, times 260 days per year, and on and on. The annual cost added by this specific activity at this specific workstation is 77,220 €. The annual revenue generated from this activity is 0 €.

4. Conclusion

In the present paper, we presented the most important aspects about lean manufacturing and the seven types of waste. Moreover, we explain and describe the types of waste with some daily life example.

This article it also focuses on lean manufacturing tools and how this tools can help a company to become leaner. It's important that a steady material flow which moves frequently in small batches will allow a faster replenishment of materials. This will then shorten lead time and increase productivity.

Lean tools that are systematically applied or implemented can help to define, analyze and attack sources of waste in specific ways. Companies store inventories to enable continuous deliveries and overcome problems such as demand variabilities, unreliable deliveries from suppliers, and breakdowns in production processes. There is a need to maintain inventories at the minimum level because excess inventories would require more valuable spaces and result in higher carrying costs. Also, quality is a major focus in lean manufacturing because poor quality management would result in many wastes such as scraps and rejects.

For future work, the authors will redefine and extend the current approach.

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